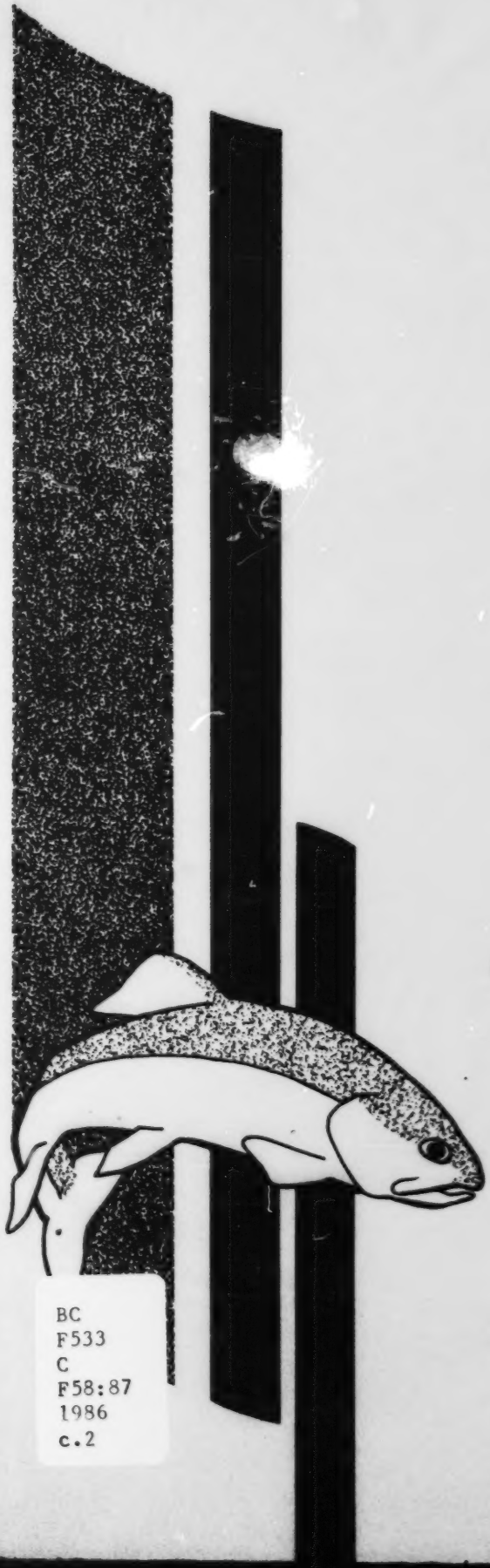

SKAHA HATCHERY EVALUATION

by

E. A. Parkinson

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E.A. Parkinson[1]

[1]Ministry of Environment, Fisheries Branch, 2374 Main Mall, University of British Columbia, Vancouver, B.C., V6T 1W5

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ABSTRACT

Parkinson, E.A. 1986. An evaluation of the relative survival and growth of hatchery kokanee released at different sizes and times in Skaha Lake, British Columbia. B.C. Fisheries Management Report No. 87, 17 p.

Size of release ranging from 1.4 to 5.5 g was not a significant factor in determining the subsequent survival of hatchery kokanee fry released into Skaha Lake. There was some indication that groups released later in the May 1 to July 30 period survived better but the relationship was weak (r^2 = .108). The lack of a relationship between survival and both size and time implies that other factors are important in determining post release survival. Although hatchery fish start out up to 18 times the size of wild 0+ fry in the spring of their first year, hatchery fish lose this size advantage and are essentially the same size as wild fish of the same age by their third summer.

ACKNOWLEDGEMENTS

The assistance and cooperation of Chris Houston, Steve Mathews and, especially, Jill and Derek Salter in rearing, marking and releasing the fish used in this study, is greatly appreciated. Population estimates in 1985 were done by Dr. Richard Thorne of the Fisheries Research Institute, University of Washington, with the assistance of his students, Joyce McClain and Dave Marino.

SKAHA HATCHERY EVALUATION

INTRODUCTION

In this paper, growth and survival of hatchery reared kokanee released into Skaha Lake at different sizes and times are compared. Studies in Odell Lake suggested that larger fish produce higher returns and that the optimal time of release is late June (Lewis 1975). The objective of this study is to test these results in a more northern lake containing additional species of cyprinids.

A second objective was to determine if a size difference between wild and hatchery fish, present at release, would be maintained in subsequent years. A final objective was to obtain estimates of survival in order to assess the feasibility of hatchery production of kokanee in this type of lake.

METHODS

Kokanee used in this study were all Mission Creek stock, reared at a hatchery on Skaha Lake using groundwater (10 and 11.5C). Variation in fish size at Skaha hatchery was obtained by incubating eggs for varying lengths of time at a hatchery on Penticton Creek where water temperatures were colder(0-2 C). Disease problems were limited to an outbreak of cold water disease in April, 1984, but all fish appeared to be healthy at release. Fish were usually released in late evening at the mouth of the main inlet stream but July releases were made directly into the lake along a steep shoreline because water temperatures in the inlet exceeded 20 C.

Release groups were marked with one of four colours of fluorescent grit using the method of Pribble (1976). In a mark retention experiment, 200 fin clipped fish from each group were held in a small outdoor pond for 6 months following the normal release time. The fish ranged between 82 and 176 mm in size at time of examination and of the 384 fish examined only one was not marked with grit.

Hatchery fish were released at the times and sizes listed in Table 1. Recoveries were made each year in the spring (March or April) and fall (September). Samples usually included 2 or 3 brood years which were separated by aging with scales.

Survival of release groups within a brood year were compared by first lumping recoveries of older fish into one recovery period, (fall 1+ and older, Table 1). A G-test (Sokal

and Rolph 1981) was used to compare the pattern of recoveries between the three recovery periods (fall 0+, spring 1+, fall 1+ and older) using total recoveries to generate expected values. If the pattern of recovery was similar among the three time periods, total recoveries were used in a series of orthoganal G-test comparisons using the numbers of fish released to generate the expected pattern of recovery. If the pattern of recoveries among the three periods was not similar, separate comparisons were made for each of the three recovery periods for that brood year.

Fish were recaptured using a midwater trawl (4.5 m square at the mouth and 11.25 m long) which contained mesh sizes ranging from 101 mm to 9 mm in the body and a zippered nylon bag on the cod end. An inner cone (mesh size 25 mm) open at the cod end retained larger fish which often attempted to escape during the final retrieval process. Towing speed was determined using a General Oceanic flowmeter and ranged from .6 to 1.2 m/sec. Towing depth was determined from line angle-length relationships, verified on one occasion using a depth sounder in another boat.

Fish abundance in Skaha Lake was estimated each September by echosounder. In 1982, 1983 and 1984 a Furuno FM-22, 200 Khz sounder with a 1.0 m/sec pulse width, a 40 log R time varied gain, and a transducer with a 5^{o} (3dB) beam width was used. The effective beam angle was calculated using the method of Hyatt and Stockner (1985) who used a similar sounder. The gain was set at only 3 standardized steps above the lowest setting that kokanee could be detected because higher gain settings resulted in fish echos being obscured by echos from an abundant Mysis relicta population. Because of this, effective beam angles were different for different sized fish and were calculated to be 7^{o} for age 0+ kokanee, 8.8^{o} for age 1+ kokanee and 9.8^{o} for age 2+ and older kokanee. Echos were counted in 5m depth strata. A weighted beam angle was calculated using trawl catches to determine the age composition of each depth strata.

In 1985 estimates were made a with dual beam echo-sounding system developed by BioSonics Inc. of Seattle. The equipment consisted of a BioSonics model 101 dual channel 410 kHz transceiver, 6/15 degree dual-beam transducer, Ross 250C chart recorder, BioSonics 171 recording interface, digital signal processor (Sony PCM), and Beta-format video cassette recorder. A portable dual trace oscilloscope was used to monitor system performance. The transducer was mounted in a V-fin towing vehicle and, using a davit, suspended alongside the boat at a depth of 0.5-1 m.

The transmit level was -6 Decibels (dB) and the receiver gains were +12 dB for both narrow and wide beam channels. A Time-Varied-Gain (TVG) of 40 Log Range was used to obtain similar echo levels from individual fish independent of depth. Other parameters included pulse width of 0.5 /sec, pulse rate of four transmissions per second, and a bandwidth of 5 kHz. Record

levels for both narrow and wide channels on the digital signal processor were set so that a five volt-peak signal just reached the recording saturation level. Calibration tones were recorded at the beginning and end of each tape so that playback gains could be adjusted to proper levels for post survey processing.

Target densities in all lakes were sufficiently low for employment of echo counting techniques (Thorne 1984). Estimates of the numbers of fish/unit area were made for each depth strata for each of four transects. Population estimates were determined by extrapolating the measured fish densities over the appropriate area represented by each transect. In 1985, confidence limits on the population estimate were calculated by repeating each transect and calculating the variance of the resulting densities.

Trawl catches indicated that over 99% of fish echos were kokanee. Using the depth stratified trawls, the total population, estimated from echosounding, was allocated among 3 age classes (0+, 1+, 2+ and older) and the various marked hatchery groups.

Two main problems were encountered in estimating the populations using the Furuno system; uncertainty about the accuracy of the beam angle measurement, and uncertainty about how dark a trace had to be to be counted as a fish echo. The trawl data that was used to apportion the population into age groups of hatchery and wild fish indicated that the proportions of the various groups varied with depth. Trawl catch data therefore had to be stratified into 3 depth strata resulting in increased uncertainty of the apportionment of the total population into the various groups within a strata. The trawl also may have been size selective, thus increasing the apportionment of fish to the younger age classes and decreasing estimates of the number of older, larger fish. The system used in 1985 should provide a more accurate estimate of the total populations but problems remained in the apportionment among age and release groups.

RESULTS

Survival

Comparison of the 1982 and 1983 release groups followed a similar strategy. Two groups of fish released in late May at different sizes were compared; then an early May and the late May groups were compared, and finally May groups were compared to the June group in a series of orthoganal comparisons.

For the 1982 brood year, the pattern of recoveries was similar for the three recovery periods, allowing a single set of comparisons using the total number of recoveries (Table 1). This comparison indicated that fish that were larger at release were

recovered at a lower rate than small fish and earlier releases were recovered at a lower rate than later releases (Fig. 1). The 1983 results are consistent with 1982 results but complicated by the variable pattern of recovery among recovery periods. In all three recovery periods, however, larger fish were recovered at a lower or equal rate compared to smaller fish released at the same time (Fig. 1). Earlier releases were also recovered at a lower or equal rate when compared to later releases.

Table 1. Times of release, sizes of release, numbers released and numbers recovered for 16 groups of kokanee released into Skaha Lake. Recoveries are broken down into those from each of the three recovery periods.

				Number Recovered			
Brood Year	Time	Size (g)	Number Released	Fall 0+	Spring 1+	Fall 1+ & Older	Percent Recovered
1982	May 1	2.0	58,000	23	10	9	.072
	May 25	2.7	113,000	25	8	7	.035
	May 25	1.4	121,000	57	12	19	.073
	Jun 21	2.5	149,000	77	23	26	.084
1983	May 6	2.8	94,000	18	19	22	.063
	May 26	3.3	127,000	19	42	29	.071
	May 26	1.6	148,000	42	60	24	.085
	Jun 29	4.3	158,000	51	44	46	.099
1984	May 2	2.8	97,000	1	9	1	.011
	May 30	2.9	103,000	7	7	1	.015
	Jun 27	3.8	78,000	11	31	3	.058
	Jul 30	4.6	*120,000	21	46	1	.057
1985	May 30	2.4	66,000	26			.039
	Jun 20	3.4	109,000	29			.026
	Jun 20	3.8	80,000	59			.074
	Jul 15	5.5	*72,000	31			.043

*Fish released directly into the lake near the northeast corner

In 1984 four groups were released at different sizes at monthly intervals. The a priori statistical test indicated that recovery rates were lower for earlier releases but a posteriori inspection revealed that recovery rates for the two May releases were almost identical and much less than those of the June and July releases (Fig. 1).

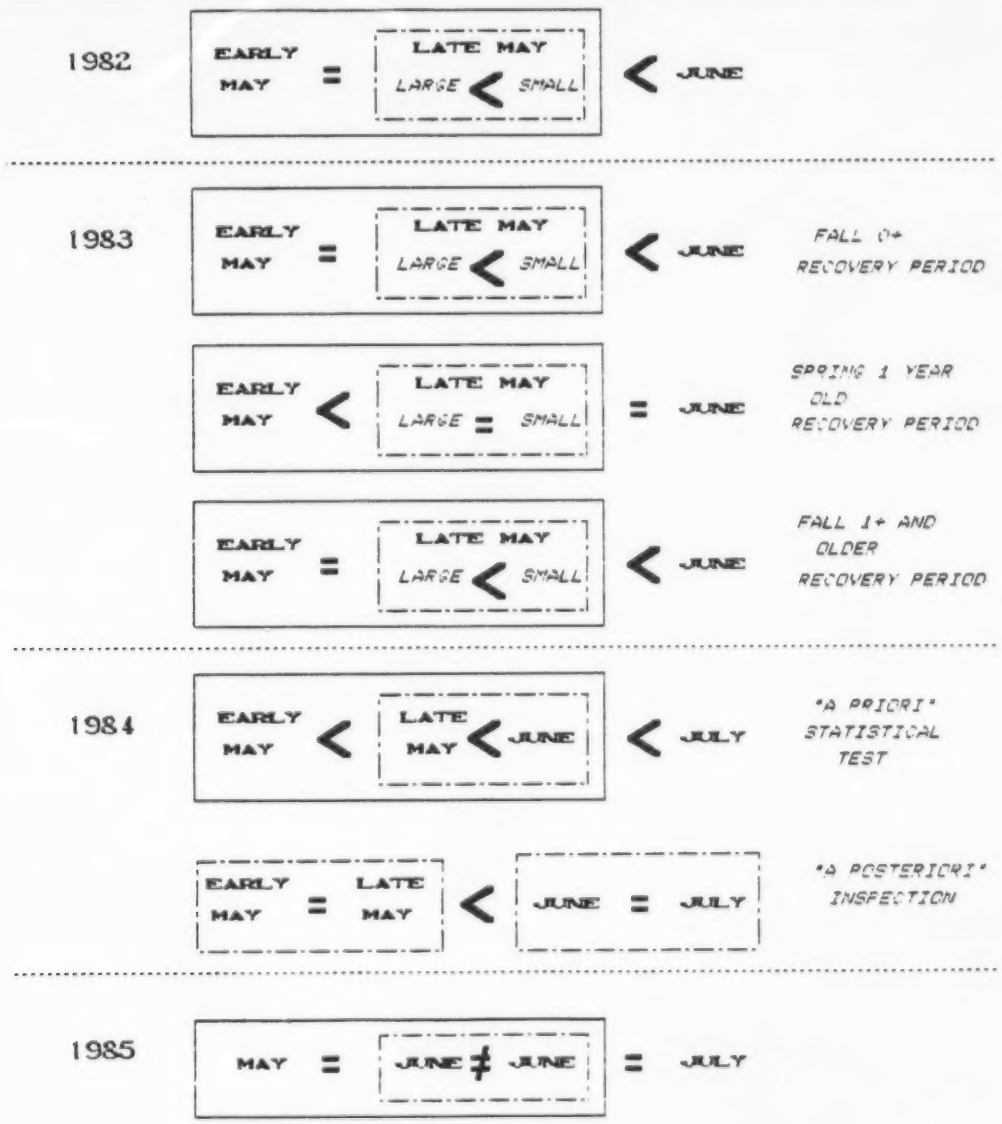
1982
EARLY MAY = LATE MAY LARGE < SMALL < JUNE
1983
EARLY MAY = LATE MAY LARGE < SMALL < JUNE
FALL 0+ RECOVERY PERIOD
EARLY MAY < LATE MAY LARGE = SMALL = JUNE
SPRING 1 YEAR OLD RECOVERY PERIOD
EARLY MAY = LATE MAY LARGE < SMALL < JUNE
FALL 1+ AND OLDER RECOVERY PERIOD
1984
EARLY MAY < LATE MAY < JUNE < JULY
"A PRIORI" STATISTICAL TEST
EARLY MAY = LATE MAY < JUNE = JULY
"A POSTERIORI" INSPECTION
1985
MAY = JUNE ≠ JUNE = JULY

Fig. 1. Summary of the detailed G-test comparisons of the number of recoveries per fish stocked in the size and time of release experiments. Details for each release group are given in Table 1. The inner dashed box encloses the first two groups to be compared. The pooled recovery rate from these two groups was then compared with that of the group within the outer box. Finally, the pooled recovery rate from these three groups was compared with that of the group outside the boxes. Signs between the boxes indicate the relative magnitude of recovery rates.

The 1985 results are confusing in that the only differences were between groups released at nearly identical sizes in June. This indicated that some of the differences observed in previous years may be due to factors not under consideration such as sublethal stress or undiagnosed disease. Recoveries were only available for one period (fall 0+; Sept. 1985) but sample sizes are relatively large (total = 145).

Results from the four years were combined in a regression analysis which used only recoveries from the fall 0+ period, combined with the population estimates to generate survivals from release. Estimates of the fall 0+ populations of hatchery fish were obviously biased upwards since the estimated survival of many groups was > 100% (Table 2). No attempt was made to correct these biases. The regression of survival to fall 0+ vs weight at release (Fig. 2a) was non-significant (r^2 = .0005) supporting the analysis of returns from individual brood years. The survival to fall 0+ vs time of release regression had a positive slope (.44) which was not significantly different from zero (r^2 = .108, Fig. 2b).

Table 2. Apparent survival of hatchery fish from release to different ages in September of successive years. Survivals from September age 0+ fish to age 1+ and age 2+ in Septembers of successive years are also given.

Brood Year	Survival from Release 0 Ave	0 Best Group	1	2	Survival between Years Wild 0-1	Hatchery 0-1	Hatchery 1-2
1982	.90	1.37	.15	.05	.15	.17	.33
1983	.88	.99	.22	.09*	.59	.25	.41*
1984	.68	1.12	.09*		.03*	.13*	
1985	.73*	.90*					

*BioSonics system used

Size and time of release were positively correlated (r^2 = .44) but this was not initialy seen to be a problem since larger size and later time of release were expected to increase survival. However, in different sized releases made at the same time smaller fish actually did better thus raising the possibility that the survival of later releases was actually reduced by their tendency towards larger size.

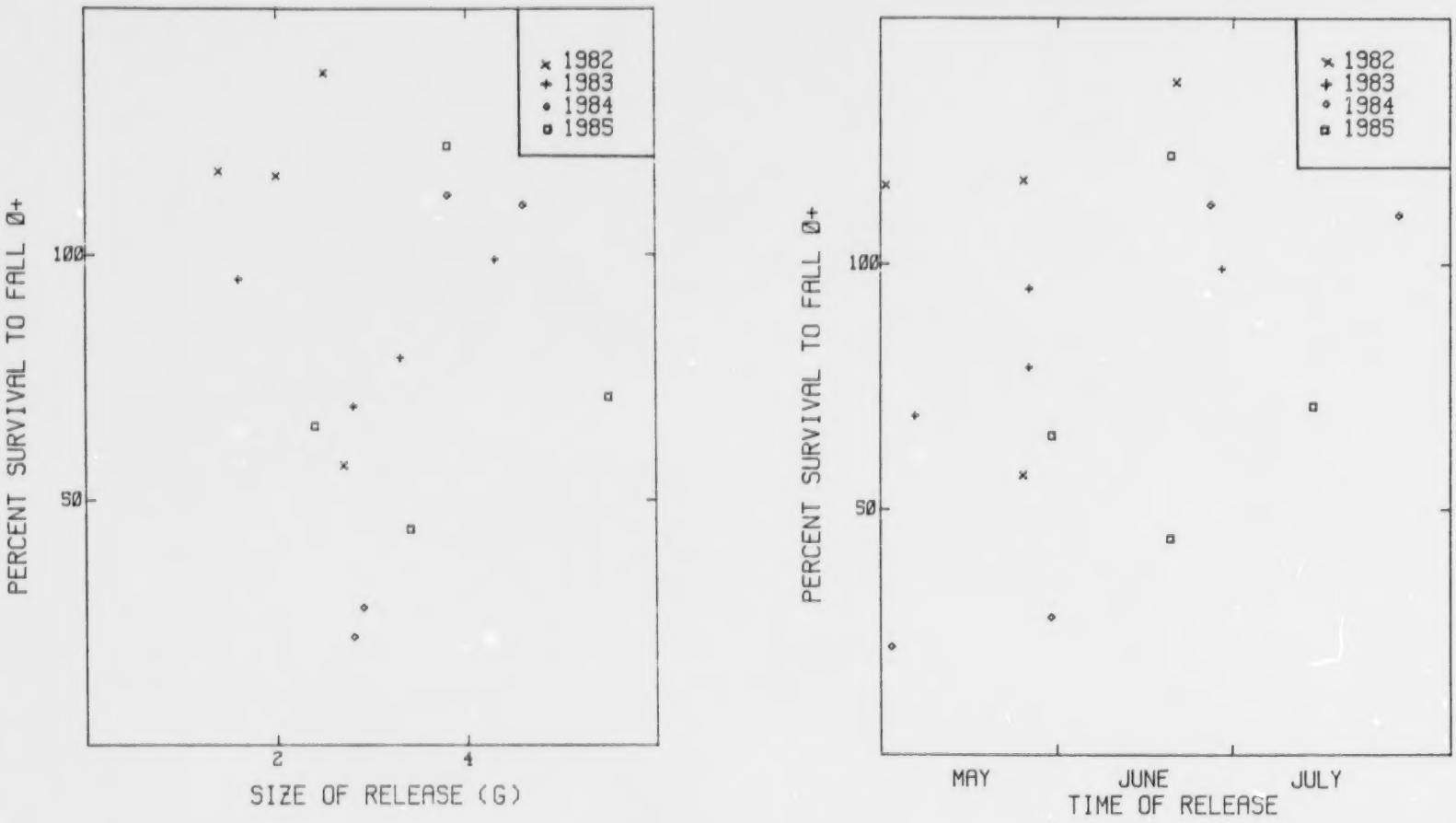

Fig. 2. Relationship between the estimated survival to fall 0+ and (a) weight of release and (b) time of release for Skaha Lake.

The best survival estimates are probably those from September 1985 which were done with the calibrated BioSonic system (Table 3). Age classes were still subdivided by using trawl data and age 1+ and 2+ fish are probably underrepresented because they are better able to avoid capture. The September 1985 release - 0+ survival (.73) should therefore be considered to be an overestimate whereas the release - 1+/2+ survivals are likely underestimates. Survivals obtained using the Furuno system are generally higher indicating that estimates obtained with this system may have an upward bias.

Growth

The weight of wild 0+ fish at the beginning of May in both 1982 and 1983 was .079 and increased to .8 g and .7 g by mid-July in 1982 and 1983, respectively. Release sizes for hatchery fish in early May of 1982 and 1983 were 2.0 g and 2.7 g, respectively, or about 25 and 34 times the size of the wild fish. July releases in 1984 and 1985 were approximately 5 - 8 times the size of the wild fish.

This size difference was not maintained in subsequent recapture periods and by age 2 wild and hatchery fish were almost the same size (Fig. 3a). Part of the reason for this is that small fish grow at a faster rate. Wild age 0 fish grow from .07 g at the end of April to about 1.8 g in mid September, an increase of about 26 fold, whereas wild age 1's grow from ~ 5 g to ~ 35 g in the same period. In addition, hatchery fish did poorly in their first few months in the lake growing from ~ 3 g in late June to only ~ 5 g by September. The net result is that the size of hatchery and wild fish of the same age converges steadily while the size of the hatchery fish and wild fish that are one year older diverges during their first summer and then slowly converges in subsequent years. In order to maintain a size equal to wild fish that are one year older, hatchery age 0 fish would have to be released at a size of ~ 8 g in April or early May.

Size differences between hatchery groups released at the same time but at different weights was also not maintained in subsequent years. For both the 1982 and the 1983 late May releases, the larger release group started out about twice as large as the smaller group but by the fall of their second summer (age 1+) the differences between groups were negligible (Fig. 3b).

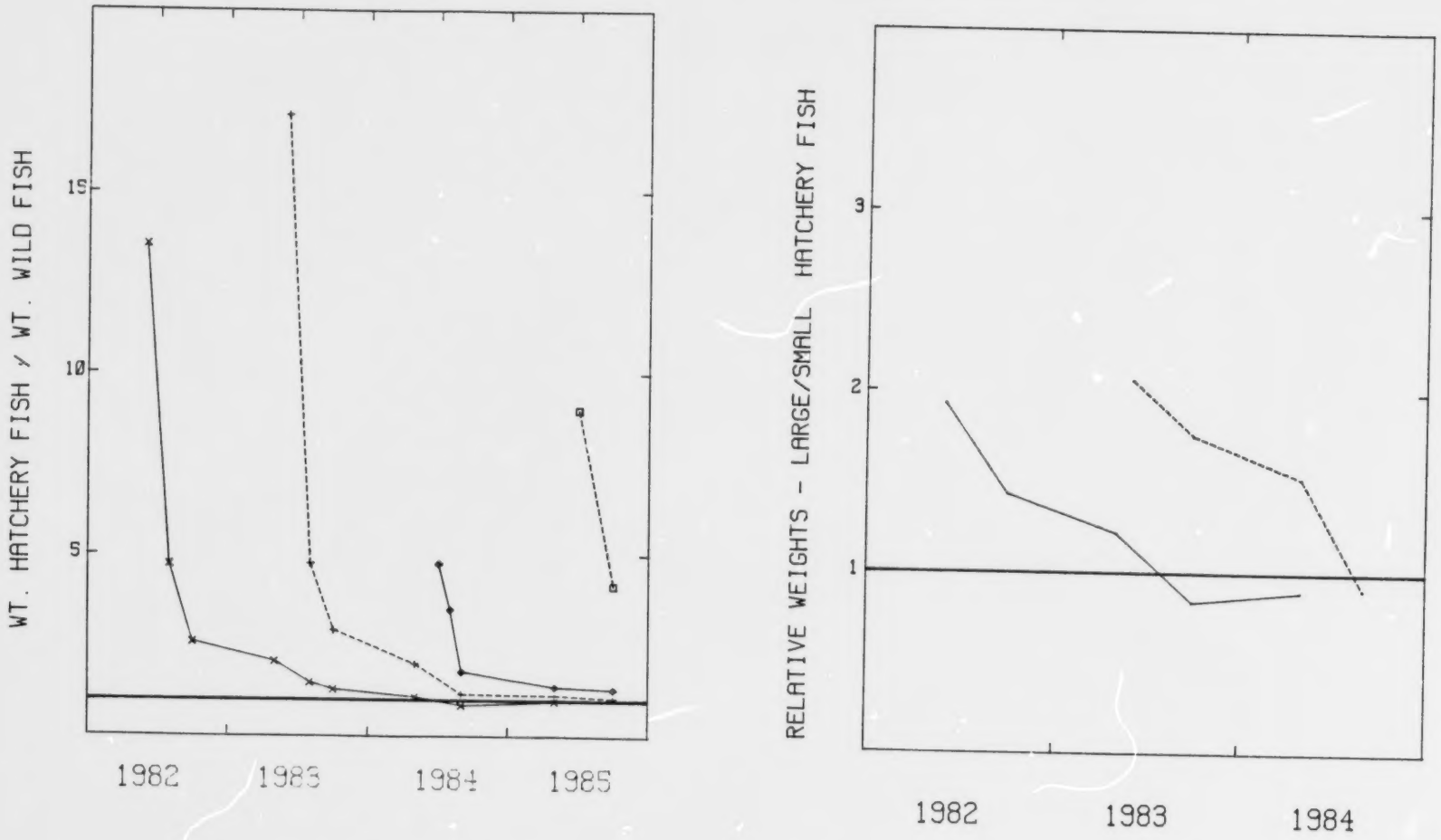

Fig. 3. Relationship of (a) the relative weight of hatchery fish and wild fish versus time for four cohorts and (b) the relative weights of large and small hatchery fish versus time for the late May 1982 and 1983 releases. Each line represents one cohort and starts in the spring of the 0+ year. The heavy black line at the bottom of each figure represents a value of 1.0, i.e. the two groups compared are of equal size. For (a), the start of each line is only approximate since it represents the mean release weight of four groups of hatchery fish divided by the estimated size of wild fish on the mean release date.

DISCUSSION

The negative effect of size on survival contrasts with other studies which generally show that survival increases with size. Adult returns increase with smolt size in a number of anadromous salmonids including, hatchery reared steelhead (Wagner 1967), Atlantic salmon (Peterson 1972) and pink salmon (Martin et al. 1981) as well as wild sockeye salmon (Hyatt and Stockner 1985) and chum salmon (Healey 1982). Largemouth bass that are large in September as age 0 fry survive the winter better than smaller individuals (Gutreuter and Anderson 1985). Size selective predation in which larger prey are either too large to be eaten (Parker 1971) or are better able to escape predators (Taylor and McPhail 1985) is the mechanism that is usually suggested.

In kokanee there is some evidence that smaller fish experience higher mortality rates. Reiman and Bowler (1980) found that back calculated growth to the first annulus increased with age suggesting that fish that were small at the end of their first year experienced higher mortality later in life. Returns to the creel in Odell Lake were weakly correlated with size (r^2=.35 p_2= .053) (Lewis 1975) but this relationship was even weaker (r^2 = .222, p = .1018) when returns were adjusted for fishing effort in the years of return and the 1965 data (which had been removed due to low effort in 1966 and 1967) was included.

The possibility that survival rate in kokanee is not related or is inversely related to size should not be completely dismissed at this time. Two major predators, rainbow trout and Dolly Varden, select large individuals (modal size 18 cm) (Ellis and Bowler 1981). In a number of other species Ricker (1969) inferred that larger members of a cohort are subjected to higher mortality rates. Werner and Hall (1974) suggest the bluegills select the largest prey that are available and can be handled by them in order to maximize energy intake. Planktivores also select the largest, most visible prey available (Zaret 1980).

The relationship between survival and time of release data was weak in both Odell Lake (Lewis 1975, Fig. 4) and Skaha Lake. An optimum time of release with respect to survival (June) was suggested for Odell Lake, but the later releases (August, September) which experienced poor survival in Odell were not made in Skaha Lake. In Cultus Lake, sockeye survival to smolting rose steadily without a summer maximum from 4.6% for fry released shortly after hatching (Foerster 1938a) to 60-70% for releases made less than a month prior to smolting (Foerster 1938b). Releases covered all time periods of the year with a minimum interval between releases of 2 months. The sizes of fry at release apparently matched quite closely those of the wild fry in the lake at the time since weight at smolting was about the same as wild fish for summer releases and about double that of wild fish for winter releases.

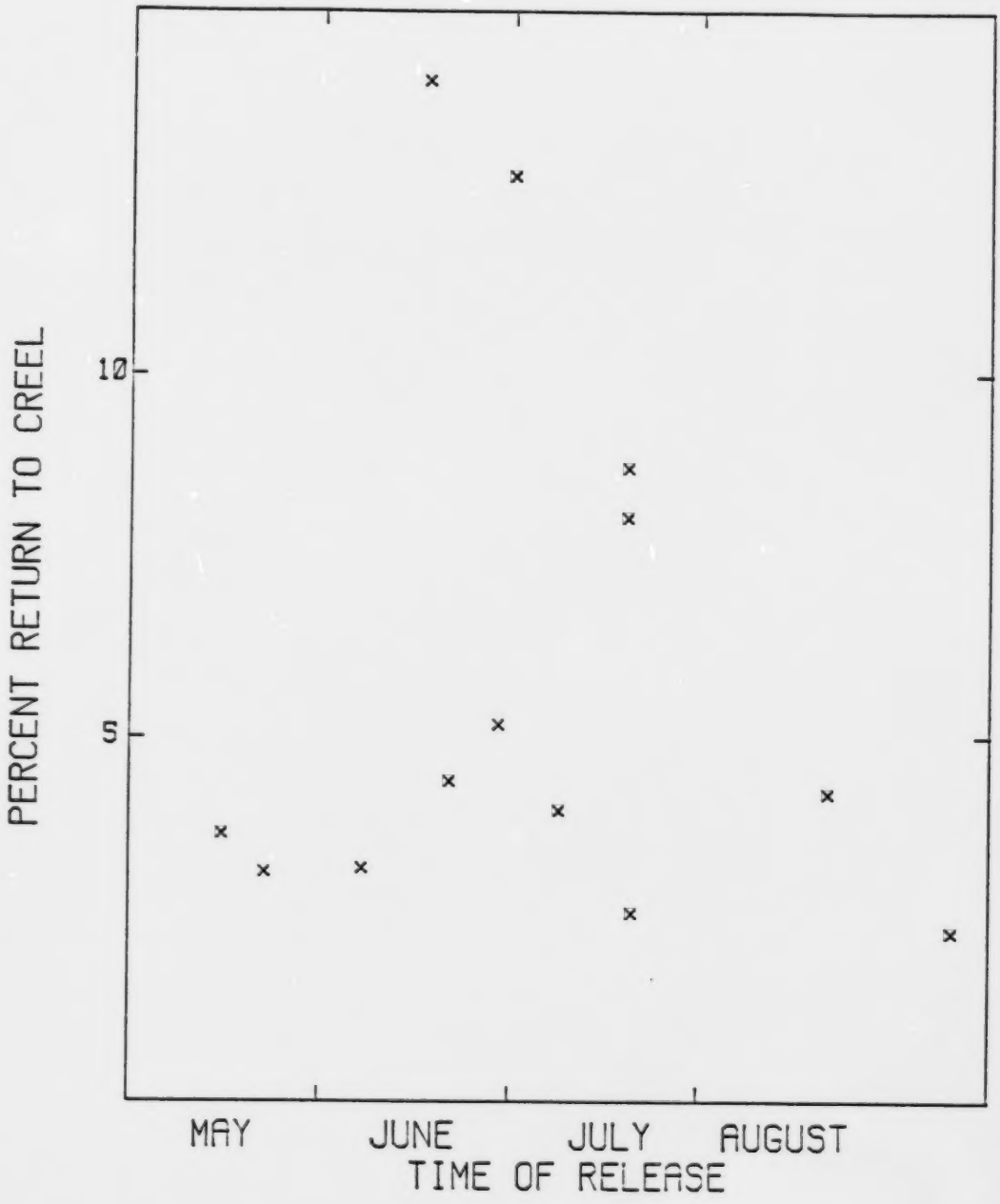

Fig. 4. Relationship between returns to the creel and time of release for Odell Lake, Oregon. Data from Lewis (1975) has been adjusted to take into account variation in angler effort during the years of return.

A sharp optimum in the time of release is present in many anadromous species (e.g. Bilton et al. 1982, coho), but this may be partially related to the timing of the physiological processes associated with smolting, as well as the number and variety of predators present along anadromous migration routes.

Population estimates of sockeye in the pelagic area of lakes do not decline significantly between July and December (Eggers 1978, Robinson and Barraclough 1978), implying low mortality rates during pelagic residence. There is, however, a spring peak in mortality for age 0 fish (Ricker and Foerster 1948, Eggers 1978), perhaps associated with the littoral to pelagic habitat transition. This can be avoided by a short period of rearing in a hatchery.

Kokanee releases should probably be timed with reference to the annual growth rate cycle rather than to natural patterns of mortality. In contrast to mortality, there is a sharp peak in growth during the summer (e.g. Lindsay and Lewis 1978) and hatchery releases should be timed to take advantage of this. Growth rates in the lake in June and July can be greater than those in a hatchery (Bowler and Rieman 1981). Winter releases would experience mortality but no growth, making it more profitable to hold these fish in a hatchery if space is available. Spring and summer releases, made at a time when the growth cycle is peaking, should produce a rapid, sustained increase in the biomass of hatchery fish in the lake even though mortality rates may increase somewhat during this period. Fall releases, made just prior to a period of low growth and continuing mortality would result in lower production.

The wide scatter in both the size and time versus survival experiments implies that kokanee hatcheries should be managed to optimize the utilization of hatchery space rather than size and time of release. Fish should be released at 1.5 g (the smallest used thus far) and experiments with smaller fish should continue. Releases can be staggered through the May-July period. Since hatchery kokanee double their weight in less than a month, a hatchery with a limited carrying capacity in terms of weight could make substantial gains in production if staggered releases were made.

The second implication of the scatter in the time and size of release data is that factors other than size and time of release are an important source of variability between kokanee release groups. For example, outbreaks of disease seem to result in higher post release mortality (Lewis 1975, Foerster 1938b). In this study, survival was lowest in 1984 following an outbreak of cold water disease prior to release. Sublethal disease infections often go undetected (Paterson et al. 1979) and may also contribute to post release mortality. Other sources of variation may include the time of day the release was made or water conditions at the time of release (e.g. turbidity,

temperature, on or off-shore winds). Some attempt should be made to control these and other factors to try to reduce the variation in future survival experiments, as well as increase our understanding of those factors that are important in the survival of hatchery reared kokanee.

Increasing the size at release of kokanee fry in an attempt to increase the size at 2+ does not seem to be effective. The apparent growth rates of hatchery fish was less than that of wild fish and by age 2 the two groups were virtually identical in size. There is no obvious explanation for the slower growth in hatchery fish since condition factors are similar.

It may be possible to accelerate hatchery growth rates to produce a release size at 0+ comparable to that of wild age 1's in early May. In Skaha Lake, wild 1's range between 4 and 7 g in April and hatchery 0's would have to be slightly larger to prevent them from falling behind in the first few months. This would be approximately 5 times the current recommended release size and heated incubation water may be required in order to reach this size by May 1. However, the gain in survival realized by skipping a year would have to be substantial (greater than 5 times in, if hatchery production is limited by weight). Since fry to age 1 smolt survival in sockeye is often > 20% (Foerster 1968, MacDonald and Hume 1984), the gains made in an accelerated growth strategy are doubtful. This strategy may, however, be useful in lakes like Kootenay Lake where age 1 sizes are smaller or where egg supplies are limited.

The survival of hatchery kokanee from release to a catchable size (2+) in Skaha Lake appears to be similar to survivals in other lakes. Survival in Skaha Lake is probably > 10%. In Odell Lake, where harvest rates average 76%, returns to the creel of hatchery fish averaged 7% if cohorts with disease problems and low fishing effort are excluded (Lewis 1975). In Parvin Lake, Colorado, about 10% of hatchery kokanee released at a length of 1.0 in (~ .1 g), either entered the creel (1.9%) or spawned (8.3%) (Klein 1979). In Pend Oreille Lake, returns of spawners from 3 cohorts released as fed fry (probably < 1 g) averaged 11.1% of the number released (Cochnauer 1984). The exploitation rate in Pend Oreille Lake in 1979 was 21% (Bowler 1980). Despite the consistency of results, it is interesting to note that the hatchery program in Odell Lake has been discontinued because wild stocks are apparently capable of sustaining the present high harvest rates, whereas the hatchery program in Pend Oreille Lake is expanding with the addition of a hatchery capable of producing up to 20,000,000 fry.

High densities can adversely affect growth in both kokanee (Rieman and Bowler 1980) and sockeye (Rogers 1980) populations. Densities in Skaha Lake are comparable with those in two other southern B.C. lakes and Pend Oreille Lake in

northern Idaho (Table 3). Growth rates in Skaha Lake as measured by weight at age in September, are higher than the other three lakes during the first and second summer but lower during the third summer (Table 3).

Table 3. Densities and weight at age in September of wild fish from Skaha, Okanagan, Kootenay, and Pend Oreille lakes.

Lake	Area (Ha)	Kokanee Density (Fish/ha)	Total Kokanee	September Weight @ Age (g) 0+	1+	2+
Skaha	2010	243	490,000	1.9	35	70
Okanagan*	34800	276	9,631,000	1.3	14	103
Kootenay*	39887	234	9,323,000	1.3	20	49
Pend Oreille+						
1974	38300	313	12,100,000			
1980		149	5,700,000	.9	21	70

*Data on file
+Data from Bowler and Reiman 1981

The benefits of a kokanee hatchery program are comparable to those of a rainbow yearling program. The survival of hatchery kokanee to catchable size is less than the 48% survival of yearling rainbow (4.1 g) in small monoculture lakes (Stringer et al. 1980) but there is less of a difference in the number of catchable fish produced per kilogram of hatchery product; 53 versus 30 for rainbow and kokanee respectively (assuming 1.5 g release size for kokanee). Other less definite factors that have to be taken into account would be the lower distribution costs in kokanee hatcheries and the smaller size of the catchable kokanee.

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